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(54) **MAGNETIC BIT SUB**

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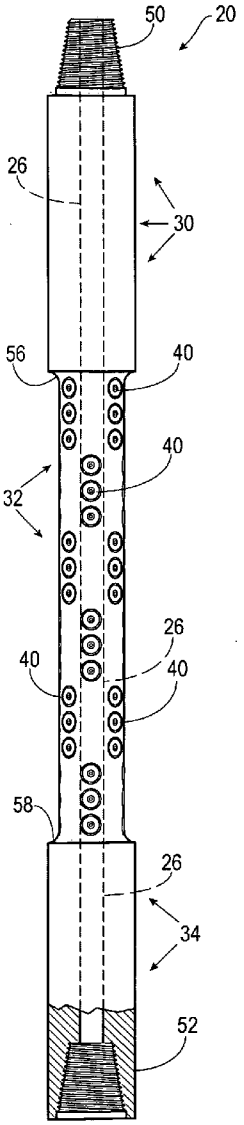
(57) **ABSTRACT**

A magnetic bit sub for collecting ferrous metal particles from oil wells, gas wells, and water wells during well drilling operations, well completion operations, and well maintenance operations provides tubular member with a threaded male connector on the upper end, for attachment to a drill string, and a threaded female connector on the lower end, for attachment to a drill bit, another portion of drill string, or another magnetic bit sub. Permanent magnets removably secured within recesses spaced along the outer surface of the tubular member collect ferrous metal particles coming into the proximity of the recessed permanent magnets for removal when the drill string is removed from the well.



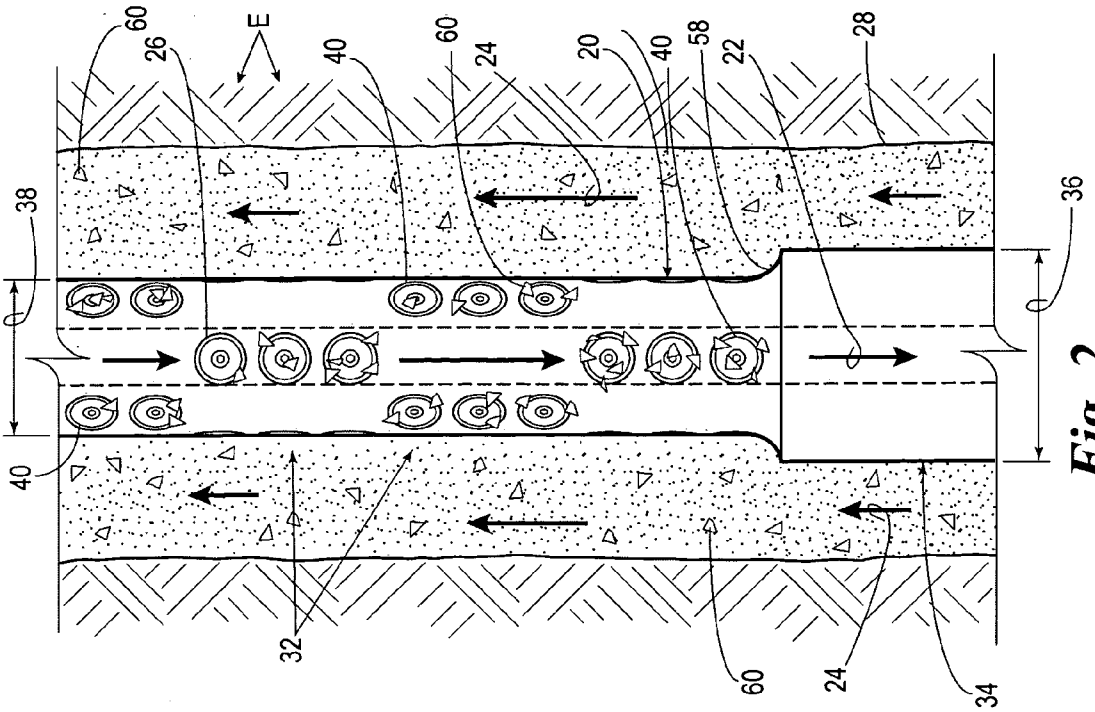

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Fig. 2

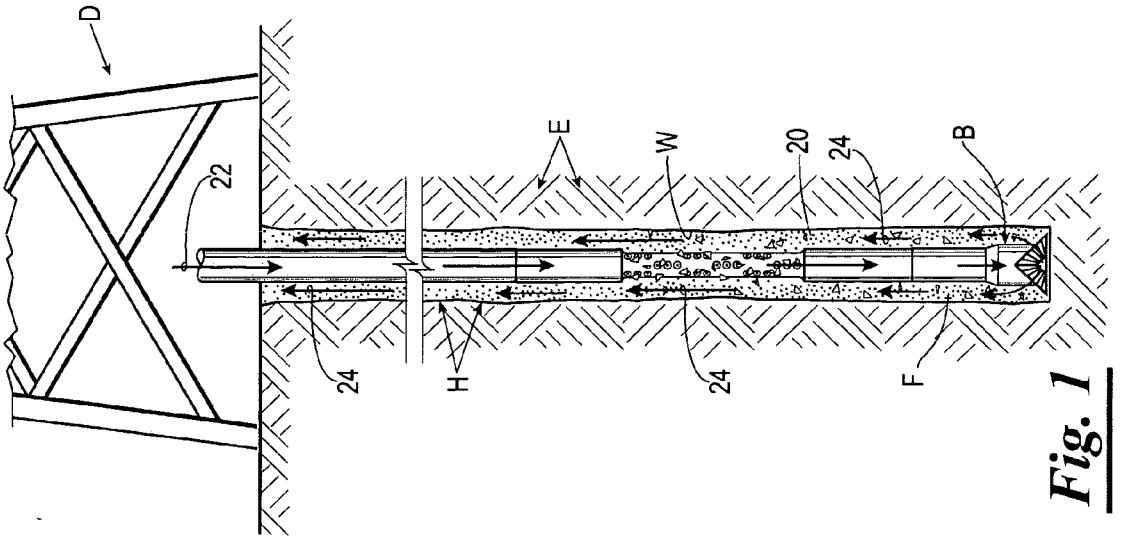
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Fig. 1

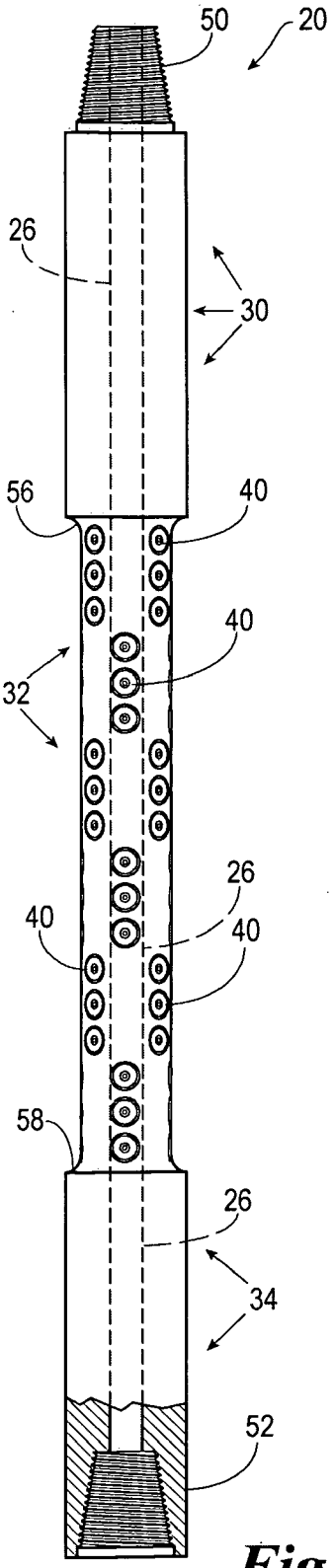

Fig. 3

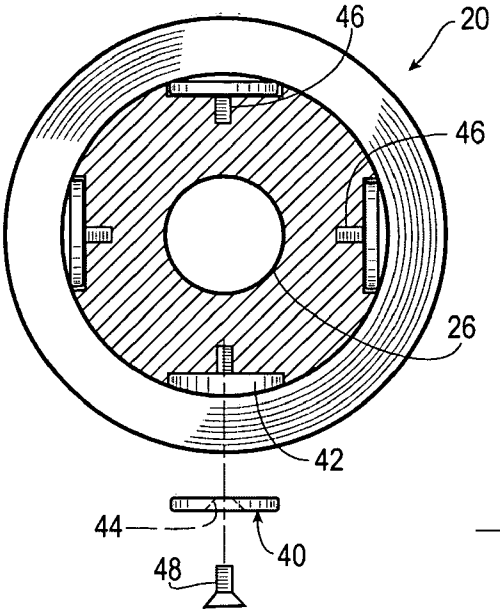

Fig. 4

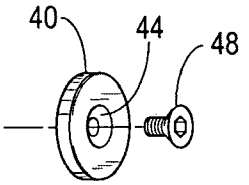

Fig. 5

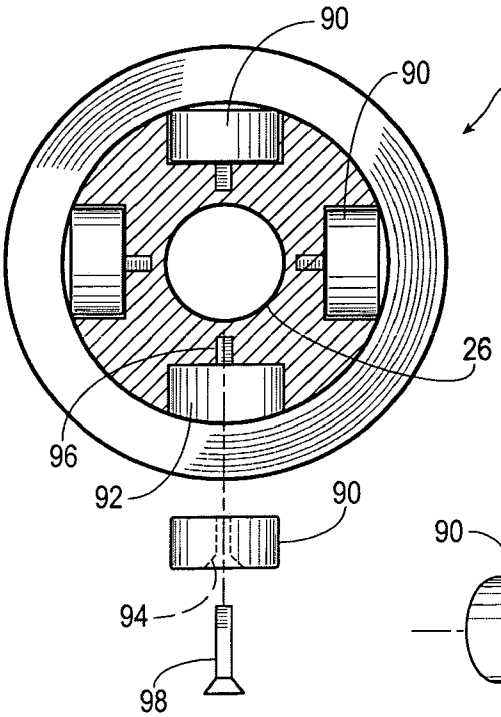

Fig. 6

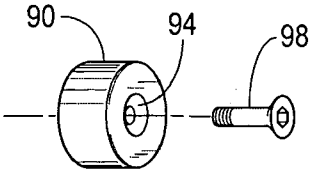

Fig. 7

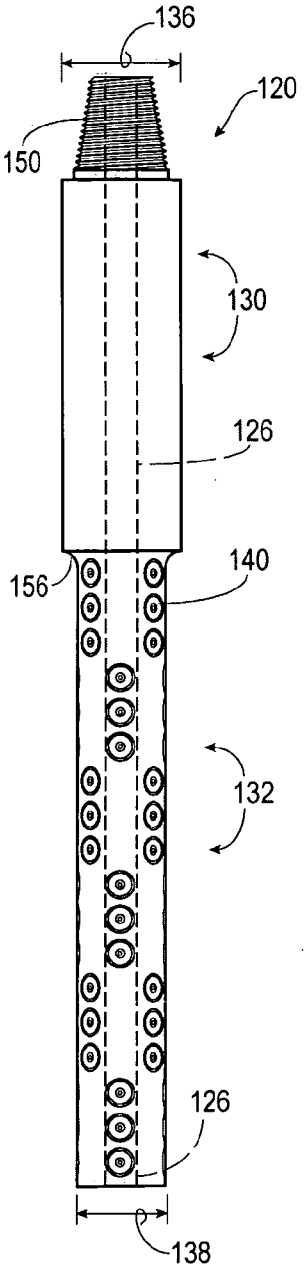

Fig. 8

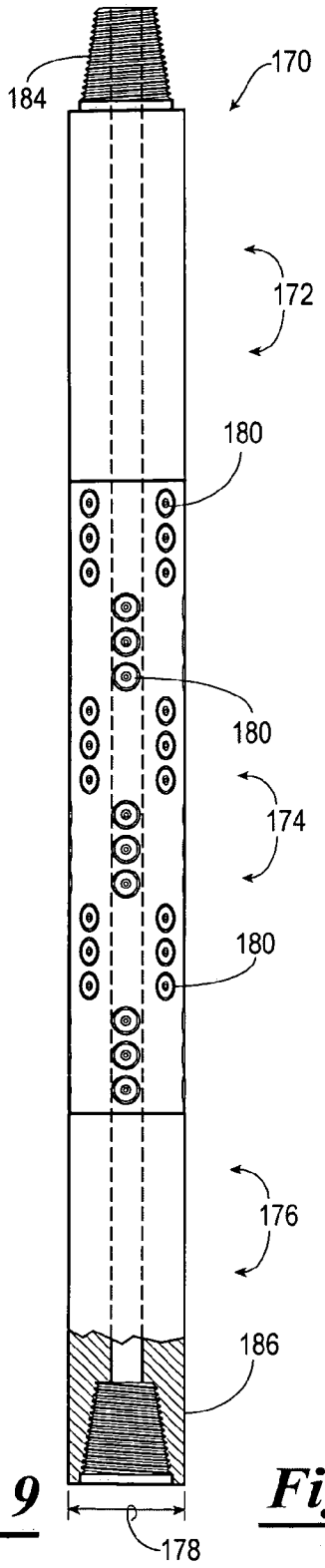

Fig. 9

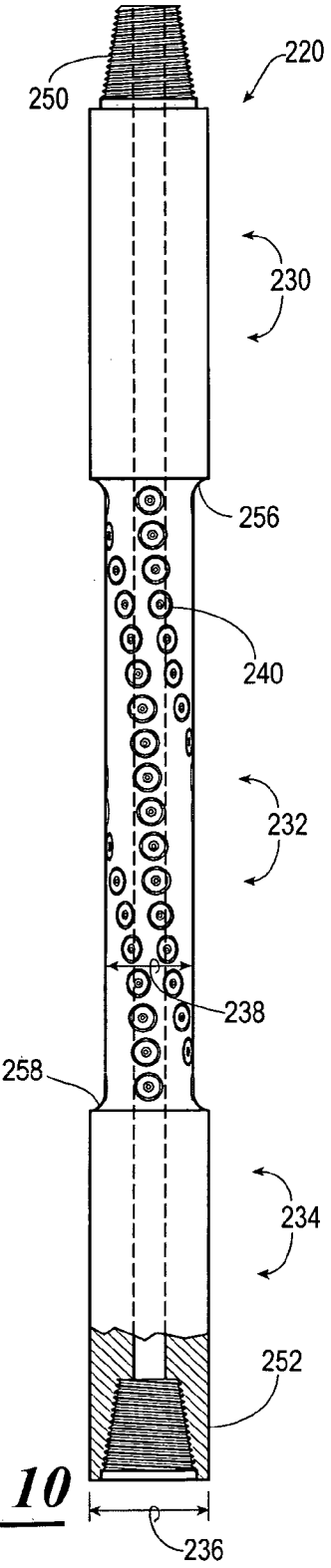

Fig. 10

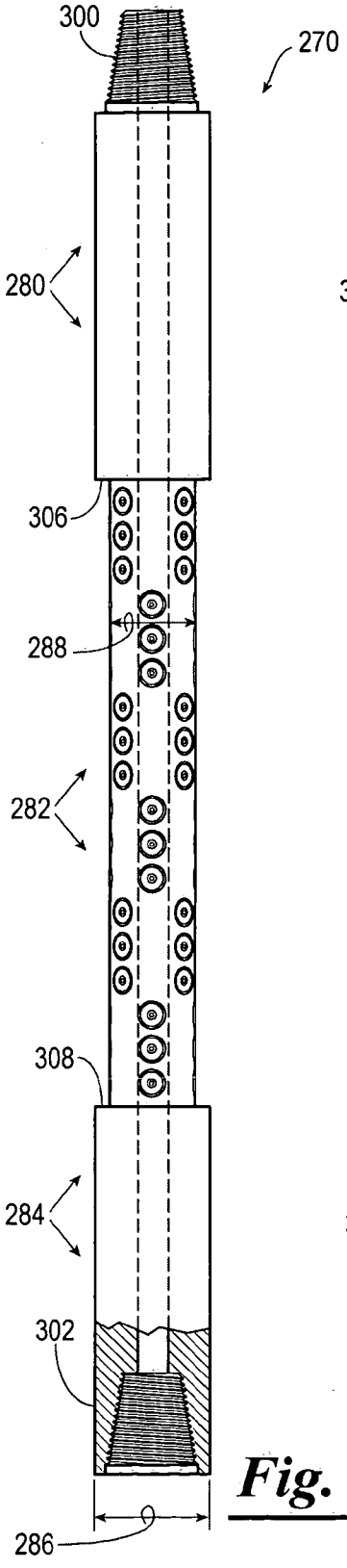

Fig. 11

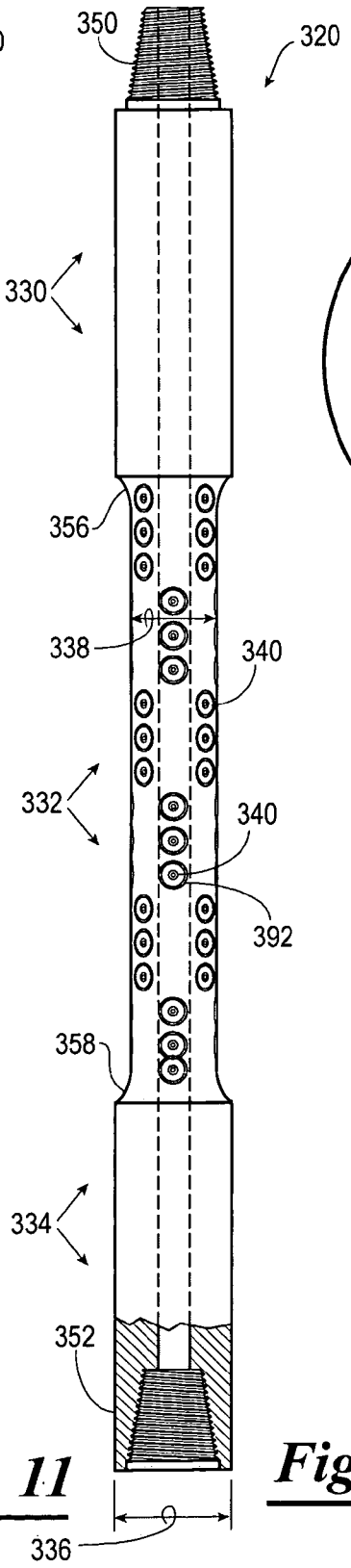

Fig. 12

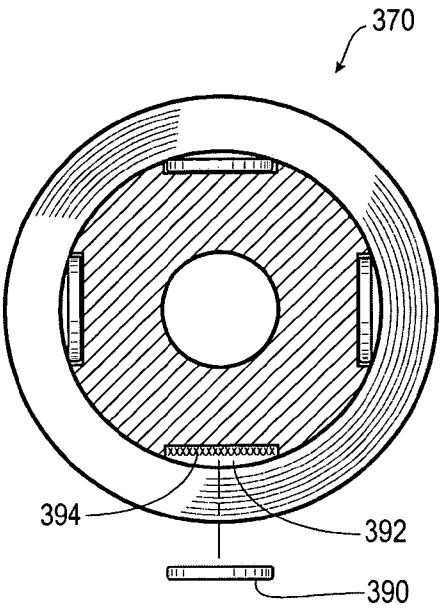

Fig. 13

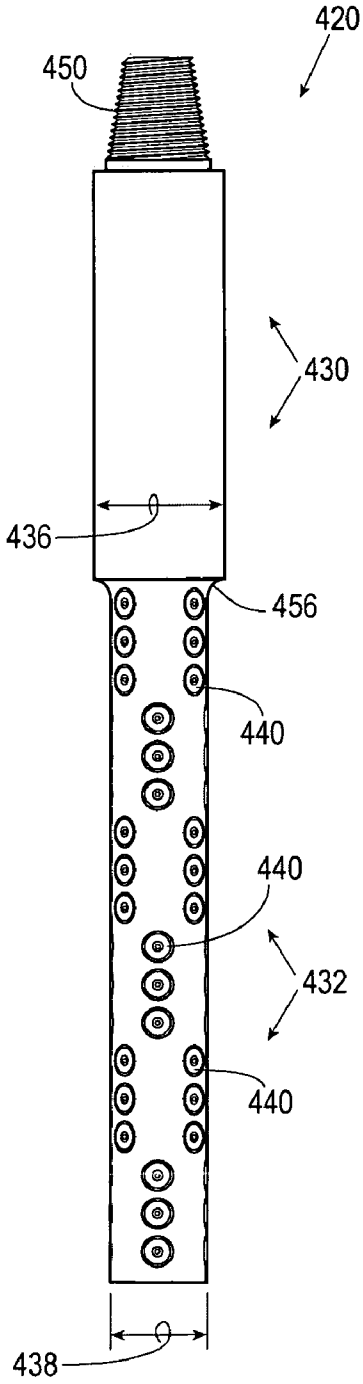

Fig. 14

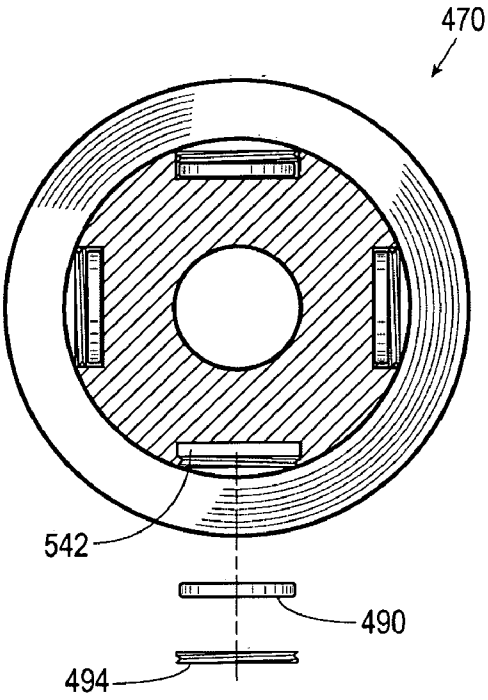

Fig. 15

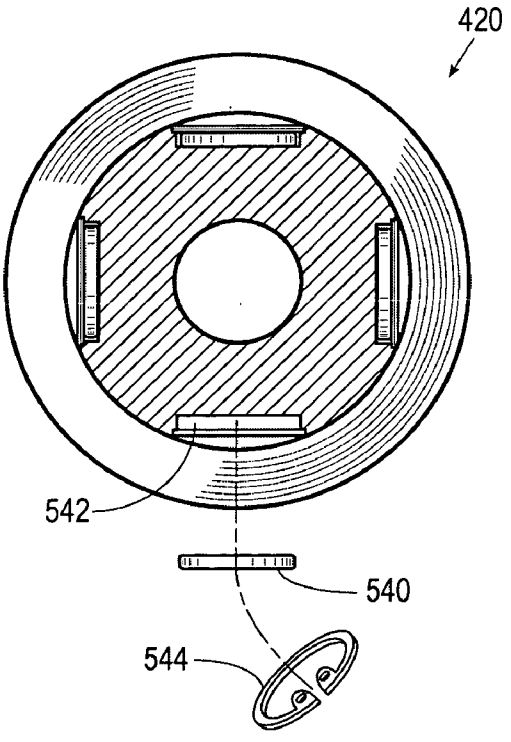

Fig. 16

MAGNETIC BIT SUB

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a well tool, and, more particularly, but not by way of limitation, to a magnetic bit sub for collecting ferrous metal particles from oil wells, gas wells, and water wells during well drilling operations, well completion operations, and well maintenance operations. The magnetic bit sub according to the present invention is also suitable for use alone to collect ferrous metal particles and objects from a well.

[0003] 2. Discussion

[0004] Ferrous metal bearing particles, sometimes referred to herein as ferrous particles, iron filings, steel filings, iron cuttings, steel cuttings, iron shavings, or steel shavings, can derive from a number of operations. Any operation which involves cutting a hole into a steel well casing will produce iron cuttings. Frac plugs, often made of steel or iron, are removed by drilling. Collapsed steel casings may be drilled out. From time to time, nuts, bolts, screws, and small tools may end up in the well, where drilling produces iron or steel cuttings. Although the description which follows focuses on oil and gas well operations, it will be understood by one skilled in the art that the magnetic bit sub of applicant's invention is suitable for recovery of ferrous metal particles and objects from any type of well.

[0005] Iron filings are not easily removed from drilling fluids using shakers and centrifuges common to oil and gas well drilling operations. The presence of iron filings leads to accelerated bit wear and other problems both in the hole and at the surface.

[0006] What is needed is a device which can be incorporated into the drill string at one or more locations to collect and retain ferrous metal particles until the drill string is pulled from the hole. The device should exhibit good strength and wear resistance, toughness, and the ability to resist stress at elevated temperatures.

SUMMARY OF THE INVENTION

[0007] A magnetic bit sub for collecting ferrous metal particles from oil wells, gas wells, and water wells during well drilling operations, well completion operations, and well maintenance operations provides a tubular member with a threaded male connector on the upper end, for attachment to a drill string pipe section, and a threaded female connector on the lower end, for attachment to another drill string pipe section or a drill bit. Permanent magnets removably secured within recesses spaced along the outer surface of the tubular member collect ferrous metal particles which are removed after the drill string is pulled from the well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a view of a magnetic bit sub according to the present invention shown in a partially completed hole beneath a derrick.

[0009] FIG. **2** is a greatly enlarged view of a portion of the magnetic bit sub shown in FIG. **1**.

[0010] FIG. **3** is another view of the magnetic bit sub shown in FIGS. **1** and **2**.

[0011] FIG. **4** is a cross-sectional view of the magnetic bit sub shown in FIGS. **1-3**.

[0012] FIG. **5** is an exploded view of one of the permanent magnets of the magnetic bit sub invention shown in FIGS. **1-4**.

[0013] FIG. **6** is a cross-sectional view of another magnetic bit sub according to the present invention.

[0014] FIG. **7** is an exploded view of another magnet which is part of the magnetic bit sub invention shown in FIG. **6**.

[0015] FIG. **8** is a view of another magnetic bit sub according to the present invention.

[0016] FIG. **9** is a view of another magnetic bit sub according to the present invention.

[0017] FIG. **10** is a view of another magnetic bit sub according to the present invention.

[0018] FIG. **11** is a view of another magnetic bit sub according to the present invention.

[0019] FIG. **12** is a view of another magnetic bit sub according to the present invention.

[0020] FIG. **13** is a cross-sectional view of another magnetic bit sub according to the present invention.

[0021] FIG. **14** is a view of another magnetic bit sub according to the present invention.

[0022] FIG. **15** is a cross-sectional view of another magnetic bit sub according to the present invention.

[0023] FIG. **16** is a cross-sectional view of another magnetic bit sub according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0024] In the following description of the invention, like numerals and characters designate like elements throughout the figures of the drawings.

[0025] Referring now to FIGS. **1-5**, and more specifically to FIGS. **1-2**, a magnetic bit sub **20** according to the present invention is attached to a drill string S above a drill bit B. The drill string S, supported by a swivel (not shown) suspended from a derrick D, is disposed within a hole H having a wall W surrounded by earth E. Drilling fluid F flows down the drill string S, as shown by arrow **22**, out through the drill bit B, and back up the outside of the drill string S along arrows **24** to the surface. The magnetic bit sub **20**, as illustrated in FIG. **1**, is located immediately above the drill bit B. As used herein, the term drilling fluid includes drilling muds, foams, hydrocarbons, and water.

[0026] Still referring to FIGS. **1-5**, and especially FIGS. **1-2**, the drilling fluid F flows (by means of a drilling fluid pump, not shown) down the drill string S according to the arrow **22** through the drill string S, through an elongated internal conduit **26** in the magnetic bit sub **20**, and through the drill bit B. The drilling fluid F then flows back to the surface according to the arrow **24** through an annular space **28** between the drill string S, the magnetic bit sub **20**, and the drill bit B, on the inside, and the wall W of the hole H, on the outside. The magnetic bit sub **20** has an upper portion **30**, an intermediate portion **32**, and a lower portion **34**. The upper portion **30** and the lower portion **34** have an outside diameter **36**, whereas the intermediate portion **32** has a reduced outside diameter **38**.

[0027] Still referring to FIGS. **1-5**, permanent magnets **40** are secured within recesses **42** (See FIG. **4**) spaced along the length of the intermediate portion **32** of the magnetic bit sub **20** to form an array of permanent magnets **40**. As shown in greater detail in FIGS. **4-5**, the permanent magnets **40** have a center counterbore **44** which aligns with threaded radial bores **46** centered in the recesses **42**. Threaded bolts **48** secure the permanent magnets **40** within the recesses **42**. The upper

portion **30** of the magnetic bit sub **20** terminates in a male connector **50**, and the lower portion **34** of the magnetic bit sub **20** terminates in a female connector **52**.

[0028] It will be understood by one skilled in the art that the magnetic bit sub **20** is suitable for placement at any location in the drill string S. Two or more magnetic bit subs **20** can be coupled to increase the number of permanent magnets **40** coming in contact with the drilling fluid F. In the alternative, two or more magnetic bit subs **20** can be placed at separate locations in the drill string S. It will be further understood by one skilled in the art that the outside diameter **36** of the magnetic bit sub **20** and the size of the connectors **50**, **52** corresponds to the pipe size of the drill string S. Magnetic bit sub prototypes have been constructed from Alloy 4140 Steel wherein the upper and lower portions have an outside diameter of about 3.75 inches and the intermediate portion has an outside diameter of about 2.75 inches.

[0029] Still referring to FIGS. **1-5**, and more particularly to FIGS. **2-3**, a transition **56** between the upper portion **30** and the intermediate portion **32** is a radius of a convenient dimension. Likewise, a transition **58** between the intermediate portion **32** and the lower portion **34** is a radius of any convenient dimension.

[0030] Referring now to FIG. **2**, particles **60** from the drilling fluid F are lodged on the permanent magnets **40** arrayed in the intermediate portion **34** of the magnetic bit sub **20**. For any constant flow rate of the drilling fluid F (as determined by the pumping rate of the drilling fluid pump), the upward velocity of the drilling fluid F along arrows **24** will decrease as the drilling fluid F moves past the lower transition **58** between the lower portion **34** and the intermediate portion **32**. The reduced outside diameter **38** of the intermediate portion **34** results in a larger annular space **28** cross section in vicinity of the intermediate portion **34**. The reduced velocity of the drilling fluid F adjacent the intermediate portion **32** and the permanent magnets **40** arrayed therein is thought to facilitate collection of ferrous metal particles **60** on the permanent magnets **40**. In addition, the reduced diameter **38** of the intermediate portion **32** provides space for accumulation of ferrous particles **60** without restricting the flow of the drilling fluid F. When the drilling fluid F moves upwardly passed the upper transition **56**, the velocity of the drilling fluid F increases.

[0031] Referring now to FIGS. **6-7**, another magnetic bit sub **70** is like the magnetic bit sub **20** shown in FIGS. **1-5** except for the dimensions of the permanent magnets. Permanent magnets **90** are secured within recesses **92** spaced along the intermediate portion **82** of the magnetic bit sub **70** (identical to the intermediate portion **32** of the magnetic bit sub **20**). Although a variety of permanent magnets are capable of functioning at ambient temperatures, Alnico magnets have been found superior in the face of high temperatures encountered in deep well drilling operations—temperatures which cause most permanent magnets to lose their magnetic strength. Of the more commonly available magnets, only rare-earth magnets such as neodymium and samarium-cobalt are stronger. Alnico alloys have some of the highest Curie points of any magnetic material, around 800° C. They are also one of the most stable permanent magnets if they are handled properly. Generally, cylindrical Alnico permanent magnets achieve a maximum magnetic strength when the thickness of the magnet approaches its diameter. Thus the magnets **90** shown in FIGS. **6-7** are relatively thicker than the magnets **40** of FIGS. **1-5**.

[0032] Still referring to FIGS. **6-7**, the permanent magnets **90** are secured within recesses **92** spaced along the length of the intermediate portion **82** of the magnetic bit sub **70** to form an array of permanent magnets **90**. The permanent magnets **90** have a center counterbore **94** which aligns with threaded radial bores **96** centered in the recesses **92**. Threaded bolts **98** secure the permanent magnets **90** within the recesses **92**.

[0033] In FIG. **8**, a magnetic bit sub **120** has an upper portion **130** and a lower portion **132**. An internal conduit **126** permits flow of drilling fluid F through the magnetic bit sub **120**. The upper portion **130** has an outside diameter **136**, whereas the lower portion **132** has a reduced outside diameter **138**. Permanent magnets **140** are secured within recesses **142** spaced along the lower portion **132** of the magnetic bit sub **120** to form an array of permanent magnets **140**. The upper portion **130** of the magnetic bit sub **120** terminates in a male connector **150**. The lower portion **132** of the magnetic bit sub **120** has no connector. A transition **156** between the upper portion **130** and the lower portion **132** is a machined radius.

[0034] Still referring to FIG. **8**, the magnetic bit sub **120** is suited for insertion into a well for removal of ferrous particles and other undesirable ferrous metal items. The permanent magnets **140** are secured within recesses **142** (not shown) as described with respect to the attachment of the permanent magnets **40** within recesses **42** in the magnetic bit sub **20** of FIGS. **1-5**.

[0035] In FIG. **9**, a magnetic bit sub **170** has an upper portion **172**, an intermediate portion **174**, and a lower portion **176**. The upper portion **172**, the intermediate portion **174**, and the lower portion **176** are of a constant diameter **178**. Permanent magnets **180** are secured within recesses **182** (not shown) spaced along the intermediate portion **174**. The upper portion **172** of the magnetic bit sub **170** terminates in a male connector **184**. The lower portion **174** terminates in a female connector **186**.

[0036] In FIG. **10**, a magnetic bit sub **220** has an upper portion **230**, an intermediate portion **232**, and a lower portion **234**. The upper portion **230** and the lower portion **234** have an outside diameter **236**, whereas the intermediate portion **232** has a reduced outside diameter **238**.

[0037] Still referring to FIG. **10**, permanent magnets **240** are secured within recesses **242** (not shown) spaced helically along the length of the intermediate portion **232** of the magnetic bit sub **220** to form an array of permanent magnets **240**. The upper portion **230** of the magnetic bit sub **220** terminates in a male connector **250**, and the lower portion **234** of the magnetic bit sub **220** terminates in a female connector **252**. A transition **256** between the upper portion **230** and the intermediate portion **232** is a radius of a convenient dimension. Likewise, a transition **258** between the intermediate portion **232** and the lower portion **234** is a radius of any convenient dimension.

[0038] While the magnets **40**, **80**, **140**, and **180** of FIGS. **1-9** are substantially vertically aligned in offset adjacent quadrants, the magnets **240** of the magnetic bit sub **220** shown in FIG. **10** are spaced in adjacent helices along the intermediate portion **232**. It will be understood by one skilled in the art that the permanent magnets **40**, **80**, **140**, **180**, **220** can be arrayed in any convenient configuration. It will be further understood by one skilled in the art that the permanent magnets **40**, **80**, **140**, **180**, and **200** will magnetize any ferrous metal to which they are attached. Thus the intermediate portions **32**, **82**, **174**, **232** of FIGS. **1-7**, **9**, and **10**, respectively, and the lower portion **132** of FIG. **8**, if made from magnetically permeable

alloys, will become magnetized and provide an additional area for accumulation of ferrous particles **60** removed from the drilling fluid F. This magnetization may extend to the upper portions **30**, **80**, **130**, **172**, and **230** of the magnetic bit subs shown in FIGS. **1-10**.

[0039] In FIG. **11**, a magnetic bit sub **270** has an upper portion **280**, an intermediate portion **282**, and a lower portion **284**. The upper portion **280** and the lower portion **284** have an outside diameter **286**, whereas the intermediate portion **282** has a reduced outside diameter **288**. Permanent magnets **290** are secured within recesses **292** (not shown) spaced along the length of the intermediate portion **282** of the magnetic bit sub **270** to form an array of permanent magnets **290**. The upper portion **280** of the magnetic bit sub **270** terminates in a male connector **300**, and the lower portion **284** of the magnetic bit sub **270** terminates in a female connector **302**. A transition **306** between the upper portion **280** and the intermediate portion **282** is substantially a right angle. Likewise, a transition **308** between the intermediate portion **282** and the lower portion **284** is substantially a right angle.

[0040] In FIG. **12**, a magnetic bit sub **320** has an upper portion **330**, an intermediate portion **332**, and a lower portion **334**. The upper portion **330** and the lower portion **334** have an outside diameter **336**, whereas the intermediate portion **332** has a reduced outside diameter **338**. Permanent magnets **340** are secured within recesses **342** (not shown) spaced along the length of the intermediate portion **332** of the magnetic bit sub **320** to form an array of permanent magnets **340**. The upper portion **330** of the magnetic bit sub **320** terminates in a male connector **350**, and the lower portion **334** of the magnetic bit sub **320** terminates in a female connector **352**. A transition **356** between the upper portion **330** and the intermediate portion **332** is a curved ramp. Likewise, a transition **358** between the intermediate portion **332** and the lower portion **334** is a curved ramp.

[0041] In FIG. **13**, another magnetic bit sub **370** has permanent magnets **390** secured within recesses **392** by an adhesive **394**.

[0042] In FIG. **14**, a magnetic bit sub **420** has an upper portion **430** and a lower portion **432**. The upper portion **430** has an outside diameter **436**, whereas the lower portion **432** has a reduced outside diameter **438**. Permanent magnets **440** are secured within recesses **442** (not shown) spaced along the lower portion **432** of the magnetic bit sub **420** to form an array of permanent magnets **440**. The upper portion **430** of the magnetic bit sub **420** terminates in a male connector **450**. The lower portion **432** of the magnetic bit sub **420** has no connector. A transition **456** between the upper portion **430** and the lower portion **432** is a machined radius. Unlike the magnetic bit sub **120** shown in FIG. **8**, the magnetic bit sub **420** has no internal conduit to facilitate flow of the drilling fluid F.

[0043] In FIG. **15**, a magnetic bit sub **470** has permanent magnets **490** secured within threaded recesses **492** by threaded retainers **494**.

[0044] In FIG. **16**, a magnetic bit sub **520** has permanent magnets **540** secured within recesses **542** by snap rings **544**.

[0045] In view of the foregoing detailed descriptions, it will be understood by one skilled in the art that the magnetic bit subs **20**, **120**, **170**, **220**, **270**, **320**, **370**, **470**, and **520** are, essentially, tubular members with one or more connectors for attachment to drill pipe or well pipe. In each instance, the tubular member supports an array of permanent magnets secured in spaced recesses along the outside of the tubular member. The recessed permanent magnets attract and hold iron particles from the fluid moving past the recessed permanent magnets for removal when the drill pipe or well pipe is removed from the well. The magnetic bit sub **120** shown in FIG. **8** has only an upper connector, so the magnetic bit sub **120** is suitable for use only at the bottom of the drill string. The magnetic bit sub **420** shown in FIG. **14** has no internal conduit to accommodate flow of drilling fluid and is also suitable for use only at the bottom of the drill string.

[0046] It will be further understood by one skilled in the art that locations of the permanent magnets within recesses provides protection from side impact of drilling chips carried win the drilling fluid. Moreover, the attachment of the permanent magnets to the tubular member by threaded bolts (See FIGS. **1-5**), retaining rings (See FIG. **15**), and snap rings (See FIG. **16**) facilitates replacement of the permanent magnets when the permanent magnets eventually wear out. Further, the recessed permanent magnets do not interfere with flow of the drilling fluid.

[0047] The tubular member which supports the permanent magnets can be made from any alloy (either permeable or non-permeable magnetically) having suitable strength, wear resistance, toughness, ductility, and an ability to resist stress at elevated temperatures. Prototypes have been made from Alloy C4140 (steel), chosen because of its use in drill collars, bolts, and rotary table shafting in the oil and gas well drilling industry. Alloy 4140 will become magnetized due to the presence of the permanent magnets. When the magnetic bit sub is positioned just above the drill bit (See FIG. **1**), the magnetic bit sub supports only the weight of the drill bit. When the magnet bit sub is placed higher in the drill string, the magnetic bit sub may be required to support the weight of a substantial portion of the drill string. Placement of the magnetic bit sub at the very bottom of the drill string (See FIGS. **8** and **14**) relieves the magnetic bit sub of any weight-bearing requirements.

[0048] The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

What is claimed is:

1. A magnetic bit sub for collecting ferrous metal particles from oil wells, gas wells, and water wells during well drilling operations, well completion operations, and well maintenance operations, the magnetic bit sub comprising:

a tubular member having a threaded male connector on one end for attachment to a length of pipe, the tubular member further having a plurality of recesses spaced along the outer surface of the tubular member;

a plurality of permanent magnets, each magnet being disposed within one of the plurality of recesses;

securing means for securing the permanent magnets within the recesses; and

wherein ferrous metal particles coming into the proximity of the permanent magnets are attracted to the permanent

magnets and held in place for removal when the length of pipe is removed from the well.

2. The device of claim **1**, wherein the tubular member further has a threaded female connecter at the other end for attachment to another length of pipe or to a drill bit.

3. The device of claim **2**, wherein the plurality of permanent magnets secured within the recesses spaced along the outer surface of the tubular member further comprises at least eight recessed permanent magnets arranged in an array along the outer surface of the tubular member, wherein the array consists of four sets of two recessed permanent magnets, wherein the recessed permanent magnets within each set of two recessed permanent magnets are aligned along the length of the tubular member, and wherein each set of two aligned recessed permanent magnets is located in a different quadrant around the circumference of the tubular member.

4. The device of claim **2** wherein the plurality of permanent magnets secured within recesses spaced along the outer surface of the tubular member further comprises at least twelve recessed permanent magnets arranged in a first array along the outer surface of the tubular member, wherein the first array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, and wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member.

5. The device of claim **4** wherein the plurality of permanent magnets secured within recesses spaced along the outer surface of the tubular member further comprises a second array of twelve recessed permanent magnets along the outer surface of the tubular member, wherein the second array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member, and wherein the sets of three recessed permanent magnets in the second array are shifted about 45 degrees around the circumference of the tubular member with respect to the sets of three recessed permanent magnets in the first array.

6. The device of claim **5** wherein the plurality of permanent magnets secured within recesses spaced along the outer surface of the tubular member further comprises a third array of twelve recessed permanent magnets along the outer surface of the tubular member, wherein the third array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member, and wherein the sets of three recessed permanent magnets in the third array are aligned with the sets of three recessed permanent magnets in the first array.

7. The device of claim **6** wherein the plurality of permanent magnets secured within recesses spaced along the outer surface of the tubular member further comprises a fourth array of twelve recessed permanent magnets arranged along the outer surface of the tubular member, wherein the fourth array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member, and wherein the sets of three recessed permanent magnets in the fourth array are aligned with the sets of three recessed permanent magnets in the second array.

8. The device of claim **7** wherein the plurality of permanent magnets secured within recesses spaced along the outer surface of the tubular member further comprises a fifth array of twelve recessed permanent magnets arranged along the outer surface of the tubular member, wherein the fifth array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member, and wherein the sets of three recessed permanent magnets in the fifth array are aligned with the sets of three recessed permanent magnets in the first and third arrays.

9. The device of claim **8** wherein the plurality of permanent magnets secured within recesses spaced along the outer surface of the tubular member further comprises a sixth array of twelve recessed permanent magnets arranged along the outer surface of the tubular member, wherein the sixth array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member, and wherein the sets of three recessed permanent magnets in the sixth array are aligned with the sets of three recessed permanent magnets in the second and fourth arrays.

10. The device of claim **2** wherein the permanent magnets are secured within the recesses by snap rings.

11. The device of claim **2** wherein the recesses are threaded and the permanent magnets are secured within the recesses by threaded retaining rings.

12. The device of claim **2** wherein the permanent magnets are secured within the recesses by an adhesive.

13. The device of claim **2** wherein the permanent magnets have a center counterbore, wherein each recess has a centered threaded radial bore, and wherein a threaded bolt through the center counterbore of each magnet mates with the centered threaded radial bore in each recess in the outer surface of the tubular member.

14. The device of claim **2** wherein the permanent magnets are alnico magnets.

15. The device of claim **4** wherein the tubular member is further characterized as having an upper portion, an intermediate portion, and a lower portion, and wherein the first array of recessed permanent magnets is located along the intermediate portion of the tubular member.

16. The device of claim **4** wherein the intermediate portion has an outside diameter less than the outside diameter of the remaining upper and lower portions, and wherein the first array of recessed permanent magnets is located along the intermediate portion of the tubular member.

17. The device of claim **16** wherein the outside diameter of the intermediate portion is about 2.75 inches and the outside of the upper and lower portions is about 3.75 inches.

18. A magnetic bit sub for collecting ferrous metal particles from oil wells, gas wells, and water wells during well drilling

operations, well completion operations, and well maintenance operations, the magnetic bit sub comprising:

a member having a threaded male connector on one end for attachment to a length of pipe, the tubular member further having a plurality of recesses spaced along the outer surface of the tubular member;

a plurality of permanent magnets, each magnet being disposed within one of the plurality of recesses;

securing means for securing the permanent magnets within the recesses; and

wherein ferrous metal particles coming into the proximity of the recessed permanent magnets are attracted to the recessed permanent magnets and held in place for removal when the length of pipe is removed from the well.

19. The device of claim **18** wherein the plurality of permanent magnets secured within the recesses spaced along the outer surface of the tubular member further comprises at least twelve recessed permanent magnets arranged in a first array along the outer surface of the tubular member, wherein the first array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, and wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member.

20. The device of claim **19** wherein the plurality of permanent magnets secured within the recesses spaced along the outer surface of the tubular member further comprises a second array of twelve recessed permanent magnets along the outer surface of the tubular member, wherein the second array consists of four sets of three recessed permanent magnets, wherein the recessed permanent magnets within each set of three recessed permanent magnets are aligned along the length of the tubular member, wherein each set of three recessed permanent magnets is located in a different quadrant around the circumference of the tubular member, and wherein the sets of three recessed permanent magnets in the second array are shifted about 45 degrees around the circumference of the tubular member with respect to the sets of three recessed permanent magnets in the first array.

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